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Wood-fired boiler use in West Virginia - 1992 to 1997

R. Bruce Anderson, Curt C. Hassler and Victor R. Hutchinson

ABSTRACT

Information is presented about wood-fired boilers in the state of West Virginia acquired by a survey done during the summer of 1997. This report updates information obtained in an earlier survey, "Wood-Fired Boiler Survey, Wood Fuel Promotion, and Small Cogeneration System Pilot Project", done in the fall of 1992 (Vasenda and Hassler 1993). The objective of this study was to provide specific information about the amount of wood residue used for energy (as fuel for wood-fired boilers) and to identify changes in the use of wood by-products for steam generation (wood energy) since 1992. The addition of three large engineered wood products firms to the state has significantly increased the amount of wood residue being generated and has changed the total number and types of wood-fired boilers being utilized. Since the last survey a new type of boiler, actually referred to as a thermal oil transfer furnace, is being used to heat oil as opposed to producing steam. Since the last survey changes in both the supply and demand for wood residue have significantly affected market factors, such as residue type, price, and availability.

INTRODUCTION

Disposal of wood residue is a concern for all wood processing industries. Although markets exist for some of the wood residue generated in converting logs into a variety of wood products, it is typical for the residue to yield minimal economic value and be considered a nuisance at best and a financial hardship at worst. Some wood products companies, and other types of industry with a requirement for process steam, make use of wood residue as fuel for wood-fired boilers. Wood-fired boilers can be an economical way to solve a residue problem and generate low-cost energy, as well as displace the energy created by fossil fuels. During the fall of 1992, a survey was conducted on the use of wood-fired boilers in the state of West Virginia. A total of 29 companies were identified as operating wood-fired boilers at that time. Each of these companies was contacted and asked to complete a survey providing general information about the company, the boilers they were operating, the wood fuel used in the boilers, and the usage for steam produced by the boilers.

In order to ascertain changes in the use of wood by-products for steam generation (wood energy) and to provide information on the current situation of wood energy in the state of West Virginia, a second survey was conducted during the summer of 1997. The objective of this survey was to determine what changes had occurred over the intervening years in the use of wood-fired boilers in the state. Of the original 29 companies surveyed in 1992, two were no longer in business and were dropped from the survey list for 1997. Five additional companies were identified as operating wood-fired boilers in 1997 (in three cases, companies refer to their units as furnaces, primarily because classifying the units as furnaces changes the way in which the units are regulated by the state's Office of Air Quality). One company surveyed in 1992 converted its boiler to natural gas in 1995 and was not included in the survey information for 1997. Therefore, the total number of companies surveyed in 1997 was 31.

METHODS

Before any survey work could be accomplished, it was necessary to identify companies within the state currently using wood-fired boilers. The 29 firms identified in the previous survey served as the starting point in developing the current list (Vasenda and Hassler 1993). An updated survey of firms involved in kiln drying of lumber identified two additional firms employing wood-fired boilers to generate process steam (Armstrong and Pahl 1996). An additional three firms were identified through the wood-fired boiler permit database supplied by the Office of Air Quality, West Virginia Division of Environmental Protection, Charleston, West Virginia (Womble 1997). Thus, a total of 34 potential users of wood-fired boilers were identified in this stage of the study. This number was modified during the course of the survey when it was determined that three of the original 29 firms were no longer operating wood-fired boilers (two were no longer in business and one had converted to natural gas).

The survey instrument used to collect information about each company's wood-fired boiler was similar to the survey developed for the 1992 survey. This survey consisted of four parts:

1. General information about the company
2. Boiler information
3. Fuel usage information
4. Steam usage information

Because of the relatively small total number of firms identified, it was desirable to contact each of the firms individually to obtain responses to the questions in each section. Data collection was accomplished through the use of telephone contacts with individuals within each company who were familiar with the boiler operation. All 31 companies on the list were contacted and responses to the survey questions were obtained.

SURVEY RESULTS

General Company Information

In addition to addresses and telephone numbers for each company, the first information obtained from each company was the name of the survey respondent for the company. The detailed information in the following sections of the survey could only be supplied by an individual who was familiar with the boiler operation and who had direct knowledge about the types and amounts of wood residue consumed. Identifying and contacting this individual was critical to obtaining satisfactory detail on the rest of the survey.

In response to a question regarding differences in hours of business operation during the summer and winter, no differences between summer and winter hours of operation were identified. All of the companies operated the same number of hours each week throughout the year. The most frequent response was 168 hours per week while the second most frequent response was 40 hours per week (Table 1). Table 1 refers to hours of business operation and not actual hours of boiler operation.

Table 1. Hours per week of business operation.

Hours	Number of Companies
40	9
45	3
40-48	1
50	2
80-90	2
120	3
168	11

Boiler Information

During the last sixteen years, the number of companies in West Virginia employing wood-fired boilers has consistently increased. There were ten reported boilers in 1981 and twenty in 1986 (Kohl, et al. 1981, TVA 1986). The 1992 survey of wood-fired boilers identified 29 companies. Of the 27 firms that responded to this survey, six companies had more than one boiler, for a total of 33 boilers surveyed (Vasenda and Hassler 1993). The present survey of 31 companies identified a total of 39 boilers, with a total of 8 companies having more than one boiler on their site.

The manufacturer and age of the boilers varied greatly. Table 2 shows the number and ages of boilers listed by boiler manufacturer. The 39 boilers listed by respondents were manufactured by 19 different companies, with Industrial Boiler, located in Thomasville, Georgia, being the most frequent response with 7 boilers currently operating. Ages of boilers ranged from 1 to 82 years with the average age of boilers being slightly over 21 years. Because a majority of the companies surveyed have been in business for several decades, the age of boiler, which can be used for long periods of time with proper maintenance, tends to increase with each survey (average age in 1992 was 18.3 years). For the 39 boilers in the survey, 24 were reported to be 15 years of age or less and 15 boilers were older than 15 years. Of the 24 newer boilers, 6 had been installed since the last survey, being either one or two years old (average age in 1997 survey is 21.3 years).

Table 2. Number and age of boilers, by manufacturer.

Manufacturer	Quantity	Ages	Average Age
Bigelow	2	17, 45	31
B & W Co.	1	60	60
Burnham	2	10, 13	11.5
Combustion Eng.	1	60	60
Erie City	3	44, 45, 50	46.3
GTS Energy	3	1, 1, 2	1.3
Hurst	3	1, 10, 82	31
Hurst (hybrid)	2	4, 10	7
Hurst (modified Keeler)	1	43	43
Industrial Boiler	7	6, 6, 7, 8, 8, 10, 23	9.7
Keeler	2	45, 48	46.5
Konus	1	13	13
Lambion	2	12, 13	12.5
Nord Fab.	1	8	8
Titusville	1	44	44
Superior	2	1, 6	3.5
Vynche	2	14, 17	15.5
Wellons	2	2, 15	8.5
Wicks	1	25	25

-- Boiler types

Heat from the combustion of biomass is most commonly moved and distributed for use in the form of steam. Steam has several advantages over other heat transport fluids. Steam uses a common and environmentally benign transport material (water). Steam also has one of the highest specific energy contents of all transport fluids, meaning that a small amount of steam can carry a very large amount of energy. Smaller pipes, valves, and pumps can be used to transport steam than are required for oils or liquid water systems.

Boiler types are typically characterized by the method in

which the products of combustion (flue gases) transfer heat to water, i.e., either firetube or watertube. In the firetube type, the flue gas products of combustion flow through tubes submersed in boiler water. The heat from the flue gases is transferred through the metal tubes to the surrounding water, generating steam. Firetube boilers constitute the largest share of small- to medium-sized industrial units (Dukelow 1981) and are generally confined to small capacities (less than 25,000 pounds of steam per hour) and low steam pressures (less than 150 pounds per square inch (psi)) (Aton, Fisher, Wyvill and Birchfield 1979). They are normally less expensive than a correspondingly sized watertube boiler, and can be more forgiving in terms of routine maintenance, especially with regard to water treatment.

The watertube type is essentially the reverse of a firetube boiler. The tubes contain the water and the combustion gases pass over these tubes. As boiling proceeds, a natural water circulation pattern is established within the tubes (Dukelow 1981). The steel watertube boiler is more suited for large capacities and high pressures due to its smaller component sizes and ability to accommodate expansion (Aton, Fisher, Wyvill and Birchfield 1979).

In addition, a new type of boiler, more properly identified as a furnace using a thermal oil transfer system, has been employed by several of the respondents to the current survey. This system uses heat from the combustion of biomass to heat oil, which can be used to heat water in a separate boiler, but is more frequently used to heat either ambient air in conditioning rooms or to heat press platens in the manufacturing process.

Of the 39 boilers surveyed, 5 were the new type thermal oil transfer system furnace, 21 were classified as firetube, 11 as watertube, and 2 as a firetube/watertube (hybrid).

-- Method of combustion

Wood-fired systems may also be distinguished by their method of combustion. Three common designs used for wood-fired boiler combustion are pile/grate burners (including the Dutch Oven), suspension burners, and fluidized bed (Vasenda and Hassler 1993). Each system has unique characteristics with regard to fuel inputs and types of process heat output.

Pile/grate burners: Boilers incorporating a pile-burning design are used where the anticipated wood fuel has a high moisture content. Grates serve to support the fuel and underfire air flowing up through the grates provides oxygen for combustion, cools the grates, promotes turbulence in the fuel bed, and dries the fuel. The Dutch Oven, one type of pile burner, is the oldest wood-burning technology on the market today (Bulpitt 1984). In this type of system, fuel is gravity fed through a chute onto the pile. High temperatures are generated and the fuel is dried within the refractory-lined chamber. Underfire air partially burns the fuel and drives off the volatiles. Burning is completed in a secondary chamber where overfire air is injected (Bulpitt 1984). Although the Dutch Oven can burn fuel of different consistencies, problems result in slow response to load swings due to the thermal inertia of the fuel pile. The most serious drawback is the low efficiency (50 to 60%) resulting from the increased heat loss due to the furnace's large surface area and absence of radiant heating (the furnace and boiler are separate) (Bulpitt 1984).

Typical thin pile burners are Dutch Oven or field-erected boilers with sloping grates. Fuel slides into the furnace on the grate. Particulate problems associated with dropping fuel in from above are eliminated. The thin pile allows more uniform air distribution as compared to a heaped pile and combustion rates can be increased more rapidly. Wet fuel can be used, but more size uniformity is required than with a gravity-fed Dutch Oven. Problems can result when blowholes are clogged in the fuel bed, especially with non-uniform fuel(Bulpitt 1984, Vasenda and Hassler 1993).

Suspension burners: A suspension burner burns fuel in suspension without a grate using a high volume of air. This type requires fuel that is relatively dry and finely hogged or pulverized. There are three groups of suspension burners which differ in the types of fuel they can burn. The *fuel/air mixer and igniter* type requires the finest and driest fuel. The *cyclonic* type can use coarser and somewhat wetter fuel; the fuel and air are introduced in such a manner that a flaming vortex is produced in the burner. The *fuel/air mixer, igniter, and vertical and cylindrical furnace* type can use the coarsest and wettest fuels (Bulpitt 1984, Vasenda and Hassler 1993).

Fluidized bed: A fluidized bed, named for the appearance of the bed during normal operation which resembles vigorously boiling water, will burn the wettest and dirtiest of fuels. The bed is comprised of the

biomass fuel and a non-combustible or inert material such as silica or limestone sand. The hot sand scrubs past particles of biomass and vice versa, heating the biomass and creating a great deal of turbulence. To force the bed into a fluidized motion, combustion air is admitted to the furnace under pressure, which must be greater than the pressure required to levitate the whole bed. If combustion temperatures are held relatively low, nitrogen oxides are prevented from forming. However, exhaust gases contain more particulate material and well-designed air quality control equipment is required (Bulpitt 1984, Vasenda and Hassler 1993).

Of the 39 boilers surveyed, there were 24 grate burners, 6 Dutch Ovens, 5 suspension burners, and 4 combination grate/suspension burners. As in the 1992 survey, no fluidized bed boilers were reported.

-- Maximum design input (capacity)

The maximum design input is the rated size or capacity of the boiler. Information was requested in terms of HP (horsepower), PPH (pounds of steam per hour), or mmBtu (million Btu). Conversion between these terms is possible using the following factors: to convert mmBtu into PPH, divide Btu value by 1,000; to convert PPH into HP, divide PPH by 34.5 (Vasenda and Hassler 1993). Both firetube and watertube boilers design input can be described in terms of BHP (boiler horsepower). As originally developed, this term was correlated with the square feet of heating surface. For comparison, all respondents' listed boiler capacities in this survey have been converted to BHP values (Table 3). As shown in Table 3, all but 5 of the boilers in the survey were

rated at least 125 BHP, which is considered the minimum for cogeneration feasibility (Haynes 1992). The average capacity for the boilers/furnaces reported in this survey was equal to 818.26 BHP.

Table 3. Number of boilers, grouped by capacity (in BHP).

Capacity (BHP)	Number of Boilers
90-120	5
125-134	4
150-200	9
250-500	11
500-1800	6
1800+	4

-- Typical operating pressure

Boilers operating at a pressure less than 15 psi (pounds per square inch) are considered to be low pressure boilers. While these are typically simpler in design and operation than high-pressure systems, they are also more efficient because the maximum amount of heat is extracted from the hot flue gases. The advantage of higher pressure systems comes with the reduced size of the boiler and steam piping for the same heat carrying capacity. Also, high-pressure steam contains significant amounts of "available energy" that can be used to do work in a turbine or engine and still retain most of the latent heat in "exhaust steam" for use in heating applications (Vasenda and Hassler 1993).

The survey showed that the majority of boilers (23 out of 34) employ high-pressure systems (with pressures averaging 97 psi) while the other 11 boilers were low pressure systems with typical operating pressures averaging 12 psi. Only three of the boilers were reported to operate at pressures that varied between summer and winter. All other systems operated at the

same pressure throughout the year.

The five furnaces in the survey employing a thermal oil transfer system cannot be characterized in terms of a typical operating pressure. While the oil in the system may be heated to as high as 475 degrees Fahrenheit, there is little or no increase in pressure as a result of the oil being heated. Rather, the pressure in the system is supplied by pumps that circulate the oil through the furnace. These pumps operate at pressures ranging between 60 psi and 150 psi.

-- Boiler operation

Previous survey work tried to ascertain whether there was a large stable demand for energy (Vasenda and Hassler 1993). This was considered as a basic requirement for cogeneration of electricity. While the present survey's emphasis was on changes in the types of boilers and fuel mixture, two questions were asked to determine the number of hours per week each boiler was operated and to determine whether or not the boiler load fluctuated significantly between summer and winter months. In general, firms tended to operate their boilers on a more constant basis than the hours of actual business operation shown previously in Table 1. The majority of respondents (operating 31 boilers and all 5 furnaces) indicated that their systems were operated around the clock for 168 hours per week. One boiler operated 120 hours (weekdays only) and another varied the number of hours between summer and winter as 40/120 (second boiler), while a third boiler was operated as a backup system, averaging 2 hours of operation per week. Boiler load fluctuation, or the amount of heat produced by the boiler, was directly influenced by the need for heat or steam for plant operation. Sixty three percent of the respondents reported boiler load fluctuation in the summer while 73 percent reported fluctuations in the winter. Increased variation in boiler load during winter months was generally attributed to additional space heating requirements.

-- Cost of maintenance

Annual cost of maintenance varied substantially among the boilers in this survey. New systems installed since the last survey generally did not report maintenance costs (startup and initial shakedown costs were not considered as part of annual preventative maintenance costs). Data was provided for 33 boilers and/or furnaces. Estimates for maintenance ranged from minimal ($500 or less) to a very large annual cost of $200,000, with an average of $17,348. As in the 1992 survey, no correlation was shown between age of boiler and amount of maintenance costs.

Fuel Usage Information

In order to determine if changes had occurred in fuel usage since the last survey, a series of questions was asked regarding the amount of wood residue generated, burned, and sold by each company. Table 4 summarizes the amounts of wood residue reported in 1997 by the survey respondents, broken down by type of residue, i.e., sawdust; bark; chips; slabs; and edgings, fines, and other. The amounts shown in Table 4 are total volumes of residue generated, burned, and sold during the summer and winter months. Differences in amounts reported for summer and winter usage were minimal. There was a one percent difference between summer and winter values reported for total residue generated, three percent difference for total residue sold, and five percent difference for total residue burned.

Table 4. Total amount of residue generated, burned, and sold for companies reporting in 1997 survey.

Type of residue	Generated	Tons per week Burned	Sold
Sawdust	3,492	1,792	1,700
Bark	5,892	3,260	2,632
Chips	2,090	162	1,928
Slabs, Edgings Fines, and Others	1,619	1,587	32

The amounts shown in Table 4 for wood residue burned represent the residue generated internally by the plant and burned there. While a majority of respondents (20 out of 31) were able to satisfy their boiler fuel requirements from internally generated wood residue, 11 firms indicated that they purchased additional residue for boiler consumption. These purchases totaled 1247 tons per week in the summer and 1205 tons per week in the winter. Purchased residue was not specifically broken down by type of residue, i.e., sawdust, bark, chips, etc.; however, most of the firms reporting purchases of additional residue indicated that this residue was most frequently in the form of sawdust.

Moisture content in wood affects the energy available for combustion. As in the 1992 survey, moisture content for wood residue burned was divided into three categories: kiln-dried, air-dried, and green (6-8%, 15-25%, and over 50% moisture content, respectively). All 31 respondents provided information regarding the moisture content of wood residue burned on a percentage basis. That is, the percentage of wood residue burned in each of the three moisture content categories was indicated. Table 5 shows that of all residues burned, approximately 69.4 percent was green, 25.4 percent kiln-dried, and 5.2 percent air-dried.

Table 5. Percentage of residue burned by moisture content.

Moisture Content	Summer	Winter	Average
Green	69.9%		69.0%
			69.4%
Air-Dried	5.5%		4.9%
			5.2%
Kiln-Dried	24.6%		26.1%
			25.4%

Steam Usage Information

Analysis of steam usage is complicated by the presence of five thermal oil transfer system furnaces in this survey. These furnaces, in most cases, do not produce steam directly. The furnaces heat oil which is used directly for heating platens in hot presses, for drying veneer, or for heating ambient air for strand drying in oriented-strand board production. In two cases, the heated oil was also used to heat water in a separate pressure vessel to produce process steam which was used to heat wax and blow soot out of stacks. The primary use of steam generated by the other 34 boilers in the survey is in the operation of dry-kilns (88 percent of the boilers in the survey provided steam for dry-kiln heating). Fourteen boilers produced steam solely for dry-kilns and another sixteen boilers produced steam used for multiple purposes including space heating, manufacturing (process steam for heating platens and for bending wood), and pre-dryers in addition to providing steam for dry-kilns. The remaining four boilers produced steam used either in space heating or directly in the manufacturing process.

ANALYSIS OF RESULTS

Changes in Boiler Operation

The majority of boilers surveyed in 1997 were also operating in 1992. The relative level of operation for these boilers, particularly in terms of the number of hours operated per week, did not change significantly from the 1992 survey to the 1997 survey. The types of wood residue burned in these boilers did change somewhat, particularly with respect to the use of more air-dried residue for heat production. The most significant change in boiler operation from the survey of 1992 to the present was the increased use of thermal oil transfer systems to generate heat. Only one such system was in operation in 1992 while five of these systems were identified in the current survey. In general, the size of these systems, either in terms of the maximum design input or rated capacity (in BHP) or in terms of the amounts of wood residue burned in the systems, was significantly larger than the other boilers identified in the survey. This larger size led directly to substantially larger, on average, consumption of wood residue burned and significantly increased the overall use of bark as the residue burned to produce heat.

Wood Residue Use

The data collected in the 1997 survey indicates that the largest volume of wood residue burned is bark which has overtaken sawdust as the major source of wood energy for wood-fired boilers/furnaces in the state. The amount of bark burned in 1997 was over ten times the amount of bark burned in 1992. The quantity of sawdust increased as well; but not to the same degree as bark. Total sawdust reported burned in 1997 was nearly 1800 tons per week which was 80 percent higher than the 998 tons per week of sawdust reported burned in 1992. Total amounts of residue generated, burned, and sold for those companies reporting in the 1997 survey are substantially

higher than the amounts reported in the 1992 survey.

Some of the differences can be explained by the larger number of companies participating in the 1997 survey; but, the most significant reason for the higher amounts reported in 1997 is explained by the type of wood products produced at the plants not surveyed in 1992. Three of the five companies added to the survey in 1997 are very large engineered wood products manufacturers who were not yet in full operation in 1992. Their operations significantly increased the amount of wood residue generated and also had a major impact on the type and amount of wood residue burned. Table 6 shows the changes in wood-fired boiler use of wood residue in the state of West Virginia from 1992 to 1997.

Table 6. Total amount of residue generated, burned and sold for companies in 1992 and 1997 Survey.

	Tons Per Week								
Type of Residue	Generated			Burned			Sold		
	1992	1997	%Δ	1992	1997	%Δ	1992	1997	%Δ
Sawdust	1,479	3,492	136%	998	1,792	80%	531	1,700	220%
Bark	969	5,892	508%	294	3,260	1,010%	775	2,632	240%
Chips	1,411	2,090	48%	32	162	406%	1,411	1,928	37%
Slabs, Edgings, Fines and Others	230	1,619	604%	221	1,587	620%	7.5	32	327%

Because of the increase in bark as a source of wood energy in 1997, the average moisture content of burned residue increased as well. Table 7. Shows the changes in the moisture content of residue burned from 1992 to 1997.

Table 7. Percentage of residue burned by moisture content for 1992 and 1997 D Survey.

Moisture Content	Summer			Winter			Average		
	1992	1997	%Δ	1992	1997	%Δ	1992	1997	%Δ
Green	58.2	69.9	20%	60	69	15%	59.1	69.4	17%
Air-Dried	.4	5.5	1,275	.4	4.9	1,125	.4	5.2	1,200
Kiln-Dried	41.4	24.6	-41%	39.6	26.1	-34%	40.5	25.4	-38%

The percentage of green residue burned increased from an average of 59.1% to over 69% in 1997. Substantially more air-dried residue was burned in 1997 as well, increasing from an average of 0.4% to over 5%. The percentage of kiln-dried residue burned decreased from 40.5% to 25.4% in 1997. It is important to note that these figures are percentages of total residue burned, which increased substantially from 1992 to 1997. Thus, the total tonnage of green residue burned in 1997 was significantly higher, averaging over 4700 tons per week, as compared to 997.5 tons per week in 1992. No indication was give as to why more supplementary wood residue was purchased for boiler fuel in the summer than in the winter.

CONCLUSIONS

Wood products companies have customarily used wood residue as fuel for their boilers. The present survey shows that bark residue has exceeded sawdust as the most prevalent source of fuel for these boilers. Although a variety of systems are employed, the overall use of wood-fired boilers within the state has continued to increase from earlier surveys. The amount of wood residue used as fuel also has increased significantly, largely as a result of the addition of several engineered wood products firms to the state's wood products industry in the last five years. Use of wood residue as fuel for wood-fired boilers can be expected to continue as a very economical way to solve a residue problem as well as generating low-cost energy while displacing higher cost energy created by fossil fuels. However, it should be noted that current trends in EPA emission regulations for facilities using boilers is having an effect on the use of wood residues as fuel. Since the 1992 survey one firm has converted from a wood-fired boiler to natural gas. The major reason given for the conversion was difficulties in meeting EPA emission standards. There was also an indication that a number of other related facilities might be converting to gas boilers in the near future, in order to meet increasingly restrictive air quality requirements.

Over the past five years thermal oil transfer systems, which generate heat directly for process use rather than generating steam, have become more prevalent due to the type of heating applications necessary in the manufacture of oriented strand board (OSB) and laminated veneer lumber (LVL). Because these systems are newer, efficient, and clean burning, their continued use must be considered to have a very positive influence on overall air quality and residue disposal in the state. The increase in the generation and use of wood residues as a fuel source has increased dramatically seen the 1992 survey. However, it should be noted that the economic growth

in West Virginia's wood industry, primarily due to the new engineered wood products plants, will not be maintained at it previous rate. The significant growth rate in residue generation can not be expected to continue and will reach a more gradual rate of increase in the coming years.

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